I. Innovation and Invention

The term "technological innovation" can be defined in several ways, but in this Report is used in a general sense to denote the technical, industrial and commercial steps which lead to the marketing of new manufactured products and to the commercial use of new technical processes and equipment. At one extreme innovation can imply simple investment in new manufacturing equipment or any technical measure to improve methods of production. At the other it might mean the whole sequence of scientific research, market research, invention, production, design, tooling, and production and marketing of a new product. It is the aim of this Report to identify some major factors which determine the competitiveness of new products and processes, in the hope that this may help clarify the significance of technological innovation for the effectiveness of manufacturing industry.

2. A major purpose of technological innovation is the commercial exploitation of technical knowledge so as to win new markets or to hold existing ones against competition, and to reduce costs of production. Scientific and technical advances generate the "invention," which provides the technological nucleus of the innovation. In the past, inventions have come mainly from individual free-lance inventors, or have emerged almost accidentally as by-products of scientific discoveries, and the rapidly growing number of new proposals placed before the National Research Development Corporation (NRDC) shows that the individual inventor remains a fruitful source of new ideas. But most inventions, particularly in industries based on advanced technology are now sought systematically by providing adequate facilities and arranging an appropriate environment of encouragement for the people who do the work, as part of planned programmes of innovation and marketing. For example, new types of fuel elements are designed to improve the power ratings of nuclear reactors, new lightweight and heat-resistant materials are developed to increase the thrust of aero-engines, and new catalysts are sought to improve the yield of chemical manufacturing processes. Because it is an integral part of the process of innovation, systematic invention falls within the compass of this Report. So also do the less dramatic innovations which are continuously introduced by both big and small firms in the effort to improve the effectiveness and profitability of their current operations and products.

II. The Problem

3. The lead taken over the past two decades by the USA in technological innovation, particularly in the newer industries, has been a major factor in her command of overseas markets in fields such as aircraft, nuclear power, computers, electronics and medicinal products. A recent OECD survey brought out this very sharply(1). Firms based in the USA have originated nearly two-thirds of the successful innovations made over the past twenty years, and also have the largest individual share, about one-third, of world exports in technically advanced goods. The proportion is even higher for some products, such as computers, which are immensely critical because of their pervasive influence throughout industry and commerce.

4. In a world in which technological competition has become so one-sided, Britain thus faces the same problem—how to adjust industrially—as do many other countries of medium or small economic size. But because of the dominant position which it enjoyed until the period of the second world war, the problem for us is in some respects more acute than it is for the others. The United Kingdom has for many years engaged single-handed in virtually every kind of advanced scientific enterprise, and while this implies a very high and sophisticated level of technological awareness, it also means that the problem of concentrating our technological effort is all the more difficult. But this is something which has to be done. The total population of the other technologically advanced countries, such as the USA, USSR, France, Germany and Japan, are some twelve times greater than that of Britain. The same numerical disproportion applies to scientific and technical manpower, to power consumption, to steel output, and to any other measure of technical and industrial strength. If there were anything like a law of averages, we should not expect any longer to contribute more than, at most, about 10 per cent of the world's new technical knowledge. Fortunately, we still do much better than average, and because of the structure of the United Kingdom economy, and in particular of the importance of our manufactured exports, the stimulus to keep up our high level of technological achievement remains.

5. Moreover with our long industrial experience and our skilled population, we are strongly placed to compete with other countries in advanced industries. The fact that we export a higher proportion of the goods we manufacture than almost any other country is a reflection of this strength. But the problems of relative size of market and of industrial structure are nonetheless also critical in relation to these other countries. All advanced countries face the general problem of technological co-existence with the USA, and are trying to adjust their policies accordingly. Internationally competitive industries can be expected to emerge among them, through the focussing of purely national efforts on to a few main lines of development, as in Japan, and through the linking up of firms into international organisations. Japanese industries—almost as a function of central Government—made their assessments of prospective market demand overseas, decided what should be the growth points of their export drives in relation to the performance of other countries which export manufactured goods, and then proceeded to tailor their efforts to meet the demands emerging on the horizon. It is clear that, as each country becomes internationally competitive in a few chosen fields, so collectively they all start to fill the industrial spectrum, thus making competition more widespread.

6. Britain has recognised the problem of concentrating its technological efforts and has already taken several steps to deal with it. As deliberate policy it does not propose following the USA into the field of large space projects. Conversely the Government is helping, to varying extents, to strengthen certain critical industries such as computers and machine tools. The small firm continues to be helped through the NRDC and the Research Associations. Industry, with the support and encouragement of the Industrial Reorganisation Corporation, has been active in promoting appropriate mergers of firms so as to make more effective use of financial and scarce

managerial, technical and marketing resources, to concentrate innovative efforts, to create stronger teams on individual projects, and to widen the markets for their products. The question is whether these efforts are going far enough and fast enough.

III. Conditions for Successful Innovation

7. Any firm, or indeed any country, engaged in world trade in advanced industrial products, must repeatedly modernise its manufacturing processes and introduce new or up-dated products if it is not to lose markets and go out of business because of competition from advances elsewhere. Hence the constant need for market awareness and for technological innovation. The latter, however, is an extremely risky activity. The history of technology is studded with examples of commercial failures ; of inventions not taken up ; of projects cancelled through daunting escalation of costs ; of innovations pre-empted by faster rivals ; and of new products spurned by an unprepared and unreceptive market.

8. Of the various factors which make for success in technological innovation, five stand out particularly. They are—

- (*a*) the direct linkage of the research and development (R and D) activities to the general manufacturing, financial, and marketing activities of the organisation as a whole ;
- (*b*) the framing of planned programmes of innovation in relation to the assessment of opportunities revealed by a sophisticated analysis of market situations ;
- (*c*) management which is not only effective technically, but which is market-orientated and dedicated commercially ;
- (*d*) a capability for achieving a short lead-time from the start of a new project to the marketing of the initial product ; and
- (*e*) a proper scale of production capacity and size of market in relation to the launching costs of the project.

9. The importance of arranging that R and D, production and marketing come under the same control, so that they constitute a single innovative activity—to ensure that new projects satisfy real market needs and opportunities ; that they are matched to the production and financial capabilities of the organisation ; that the commercial policy-makers are alerted to new technical means for meeting long-standing needs ; and correspondingly that the scientists and technologists appreciate the commercial facts of life—has been repeatedly stressed by those experienced in technological industry(2). Nevertheless, this basic requirement has been much less appreciated in the countries of Western Europe than in the USA(1). A recent analysis of major industrial innovations shows the effect of this clearly(3). Of the inventions which led to these, ten were initiated by Britain, France and Germany, and 19 by the USA ; but only seven were converted into final product innovations by the European countries, as against 22 by the USA. One major strength of American industry has lain in its ability to carry an idea through to the final product without a break in the innovative chain. Another has been a readiness of banks and private investors to finance technological innovation.

A third has been the scale and impact of Government purchasing policy. In particular, and since the end of the Second World War, the United States Government, with the enormous resources it was able to command, has supported a huge and pervasive military establishment, which has constantly demanded more and more sophisticated equipment, and which in so doing has been an extremely potent force both in raising domestic demand in general, and in generating the sense of technological awareness which characterises so large a part of the vast home market of America today.

10. Effective leadership by management is obviously necessary to secure the required integration of technological and trading policies. The general management—the Board of Directors in a firm—has the responsibility of setting an overall policy which takes account of all the technical, production, financial, and marketing factors; and then of ensuring that the varions departments of the organisation understand the need to co-ordinate their activities within the framework of this policy, at the same time securing the full co-operation of the whole labour force in the ensuing technological changes. Strong technical leadership from management is also needed, moreover, to provide the driving force to push new projects forward against all the resistance to change which is inevitable in almost any organisation. Enthusiasm and determination are vital factors in forcing inventions through to success(⁴).

11. Given a decision to go ahead with a new development, a short lead-time is equally essential. One reason for this is purely economic. Innovation costs money. The shorter the time between the start of a project and its commercial fulfilment, the sooner the commercial returns. Since £100 to be received in, say, five years' time is worth far more than £100 in 30 years' time, because it could be earning interest in the meantime, long-term projects are less economically attractive than short-term ones, except when the expected pay-off from them is exceptionally high.*

12. A scientific discovery may take many years before it finds practical application. It follows, therefore, that the case for supporting long-term scientific research cannot be argued on economic grounds. The justification for it is that this constitutes the fount of all new knowledge, without which the opportunities for further technical progress must eventually become exhausted. Laboratories carrying out long-term basic researches which stretch techniques to the limit are at the same time a valuable forcing ground for new technical developments. The scale of applied research and advanced development must, however, be necessarily determined by economic considerations, since these activities may culminate in a practical invention in something like three to seven years. A corresponding period may be required for the engineering development which transforms the invention into a full prototype ready for commercial development. Minor developments may take as little as one to two years; and newly installed production plant is normally brought into full use in about this same time.

---

* The discounted cash flow formula, $100/(1+r)^n$, which gives the present value of £100 to be received in n years' time with an annual discount rate r, brings out this point. For example, at a discount rate of 8 per cent. a year, £100 which will be received in 30 years' time is worth only £10 today, but its present value is increased to £46 if it can be received in ten years' time and to £68 if received in five years' time.

13. Several firms and countries have prospered through a policy of avoiding long lead-times and heavy development costs by buying other people's technological knowledge and by concentrating on the commercial application of imported inventions and innovations. The royalty and licence costs are usually small compared with other commercial outlays and returns. Britain has pursued this policy less than have some countries of similar size which because of the devastation of war had to embark on vast programmes of industrial reconstruction. In 1964, for example, we spent only some £50 million on royalties and licences, well below one-tenth of what we spent on our own R and D, and less than we earned from royalties we sold(5). At about this same time, France and Germany, which have prospered greatly in recent years, each spent on foreign royalties nearly three times as much as they earned from receipts on their own. Japan has been particularly successful in pursuing the same policy. Even in the USA it is common practice to buy other people's technical knowledge. For example, 15 of the 25 major innovations made by du Pont, a powerful science-based organisation, came from inventions made outside the firm(6).

14. On the other hand, no country could expect to progress in industries based on advanced technology just by buying in other people's ideas. Such a policy succeeds when the company which proposes to operate on a royalty basis for a particular technological product is itself under dynamic technical and commercial direction, and is an innovator in its own right. There have been United Kingdom companies which have gone downhill simply because they failed, either for lack of the right kind of staff, or because management was too feeble, to take advantage of technical information freely handed over by an allied American company. Equally it is known that United States subsidiaries in the United Kingdom, particularly those which are United States-managed, often do better than corresponding United Kingdom companies. Clearly vigorous commercial and scientific management is every bit as important as an idea which is being exploited, whether it be home-grown or imported. Moreover, as emphasised below, it is in the final stages of the process of innovation, in tooling up, in introducing improvements in processes, in skilful and aggressive marketing, that the biggest effort in terms of professionally trained manpower is called for. Thus, while buying royalty rights and so saving resources in the stages of R and D and invention can undoubtedly help to reduce lead-times, it cannot compensate for any lack of technological and commercial ability in the later and more costly parts of the process of innovation.

15. There is, of course, an even more important sense in which a short lead-time is a great advantage. The critical phase of an innovation is the sequence of actions which is set off by the decision to try to make a commercial venture out of a new idea or invention. Because this decision must be based not only on an assessment of the potential market, but on existing "state of the art" knowledge, much of which is publicly known, people may be generally aware that such an innovation has become technically possible and several rival attempts at the project in question—such as a jumbo jet aircraft, an integrated-circuit computer, a fast nuclear reactor—may then begin simultaneously. Usually, the markets for the new product are won by the team with the shortest lead-time, because this will be first with goods

to sell. In fact, efficient companies may still capture the large-scale market, even where they have delayed their start until their rivals have exposed some of the technical snags, or until the market prospects have become more firmly crystallised. This is the most decisive advantage of an ability to achieve short lead-times, or of an ability to persuade prospective customers that they can be achieved.

16. In recent years many American firms have achieved shorter lead-times than have their competitors in other countries. In electronic capital goods such as computers and telecommunications equipment, their lead-times have been about three-quarters those of British firms, which has given them a start of about a year in the large-scale production and marketing of such goods(7). Similarly, in aircraft development and production, we read that "American industry appears to compress by about one year the time taken between first flight of a new aircraft type and its introduction to service. This saving in time has often proved a decisive advantage since they have been able to embark on a project later than our own industry and yet offer earlier delivery dates"(8).

17. The American advantage in lead-times does not always emerge at the research stage; indeed, some firms make a practice of starting late in major new projects. The more successful American corporations mostly dominate in the final stages of innovation, where a more integrated organisation, better marketing, better systems planning, a more intense development effort and higher productivity enable them to push ahead. In a new aircraft project, for example, intense development before first flight ensures a smoother and quicker passage of the aircraft through its flight trials; and high productivity, in the form of rapid production of prototype aircraft for trials and in the use of a shift system in these trials, concentrates more flying in a shorter time(8, 9).

18. The stakes at risk in intensely competitive fields, measured in terms of the size of market which may be won or lost, are generally out of all proportion to the increases in launching costs necessary to moderate those risks substantially. With aircraft, in for example the £2 to £5 million class, a 25 per cent increase in launching costs, which might take six months off the lead-time, could be recovered by selling 20 additional aircraft(9); but the prize could be a market for over 200 aircraft. Every development project in a field of intense technological competition ought then to become a crash programme, so as to maximise the chances that the project will become a commercial success. Such a policy does not of course guarantee success, especially if the competition has reached the level where, for example, sales are made below cost price in order to capture markets. But its converse, a slow development due to inadequate resources, a lack of urgency, or hesitant backing, is a sure guarantee of failure. Quick decisions, leading to aggressive development and sales, are vital if markets are to be won.

19. The pressure to innovate varies greatly from one industry to another. It is at its most intense in rapidly changing fields where products become technically obsolescent within a few years, and is weaker in more traditional fields and also in those industries where the rate of change is largely controlled by investment in expensive capital plant. In almost all cases,

however, as a project moves forward from basic laboratory research to pilot-scale development and then on to first full production, the costs of innovation mount spectacularly. For example, Terylene was invented in a laboratory running at under £20,000 a year. But when Imperial Chemical Industries obtained the United Kingdom commercial rights, it then spent £4 million on pilot-plant development and £15 million on new plant for first major commercial production(4). An American survey(10) has shown that, as a general rule, only about 5 to 10 per cent of the total launching cost of a successful new product goes into the R and D leading up to the invention; and only about 10 to 20 per cent into the development and design work which then prepares the project for production. All the rest is consumed in tooling and engineering for production, and with the initial costs of production and marketing. These figures should not be taken as more than illustrative. Much depends on where the boundary between development and initial production is drawn. The figures would not, for example, normally apply to aircraft projects in which the costs of prototype machines and flight trials are charged to development. Nevertheless, in much of industry the total launching cost of a really novel innovation is often some ten times larger than the cost of the R and D for the project. At the same time, not all R and D is aimed at new products and processes; about one-half of the total industrial R and D effort is concerned with problems of current production. and with various technical services(11). Total innovative expenditure is then, on the whole, roughly some five times larger than total R and D expenditure. This is reflected in the fact that, in many countries, total annual investment in new plant and equipment runs at about 10 per cent, and R and D at about 2 per cent, of the Gross National Product (GNP) (12, 13).

20. Even in research-intensive industries such as the electronics industry, it is usually necessary that no more than about 10 per cent of the unit selling cost of the product should be allocated to R and D if the product is to be competitive in costs. For example, the total R and D effort for a computer, costing about £200,000, including software, might amount to some £15 million, but as competitive lead-times for this kind of product are about three years, about £5 million a year has to be spent in developing the machine. If the R and D per computer is costed at 10 per cent of the unit selling cost of £200,000, then 250 computers must be made and sold each year, to give an annual turnover of £50 million. To produce this output, some £50 million of investment in manufacturing plant might be needed. These figures fix the minimum viable size of market, output and capital investment of the computer firm or computer section of a larger firm. The manpower needed then depends on productivity. If the annual turnover per employee is £2,500, a force of 20,000 is required. If labour productivity is higher, fewer are needed. The more productive a firm is, in relation to the resources at its disposal, the more it can afford to spend on innovation to increase its competitiveness.

21. A similar example could be given for an aircraft project, except that here some of the equipment for production is acquired during the development phase of the project, so that R and D accounts for a large share of the launching costs (8, 9). With an R and D outlay of say £100 million and a unit selling price of £2 million, at least 250 aircraft have to be sold if the

R and D cost per aircraft is to be held at no more than 20 per cent of the selling price. The advantage to the American aircraft industry of the huge domestic American market shows up plainly here. About one-half of world civil aircraft purchases are made in America, which is some 12 times as much as British domestic purchases and four times as much as those of Britain and the European Economic Community countries combined(⁸).

22. Although scale of production and skilful marketing facilities are essential for the full commercial exploitation of major innovations, the advantages certainly do not all lie with the large firm. The small firm with a technically alert management can enjoy a flexibility and quickness of response which is rarely possible in a large organisation governed by a complex administration and weighed down by heavy investments in existing production plant. The time taken for decisions can be kept to a minimum when top management is able to know directly the technological problems that are being wrestled with throughout the firm, or in a division of a decentralised firm. And there is less danger of technical recommendations becoming emasculated and information diluted and transformed by passage through a network of committees or other intermediaries. The most difficult area for technological innovation is clearly that of major projects, which calls for both the manufacturing and marketing size of the large firm and the flexibility and technological responsiveness of the technically alert small firm. The problem is much simpler in fields where individual projects are small, so that a given firm can be organisationally small enough to retain the advantages just mentioned, and yet large enough, in relation to the launching cost of a project, to be able to assure a proper relation between R and D, total innovative costs, productive capacity, sales drive and size of market.

IV. Innovative Effort in Britain

23. As has been said, Britain shares with America the tradition for engaging in all sectors of advanced technology—apart from large space projects—and for pursuing all technically promising ideas and lines of product in each sector ; for maintaining in fact an almost completely self-sufficient indigenous technological capability. Not surprisingly the industries in the two countries have, with a few exceptions such as shipbuilding and textiles, developed to a relatively similar pattern within the total output of manufacturing industry, particularly in research-intensive sectors such as aircraft and electronics (see Table 1*).

24. The way the total R and D effort of the two countries is deployed in turn reflects the similarity of the pattern of manufacturing industry as a whole (Table 2). In terms of numbers of qualified manpower, the number of men engaged in R and D in most industrial sectors of America is, however, about five times greater than in Britain, a ratio which reflects the difference in size and wealth of the two countries. Per man employed, the ratio of American expenditure on R and D is even higher, due, partly at least, to

---

* Tables are given at the end of the report.

the higher salaries paid. The impact of this five-fold difference in the overall industrial R and D efforts of the two countries is to some extent lessened by the fact that, amongst the biggest firms in which most of the R and D is done, British industry is rather more integrated than the American, and its labour costs materially lower. Thus, some single large British or European/British corporations are similar in size to their American counterparts, in terms of total manpower employed, and so could support R and D efforts as large as those of individual American corporations, given, of course, that their effective size and lower labour costs were not neutralised by lower productivity (Table 3).

25. The effect of the British tradition for engaging in depth in all kinds of scientific industry, continued into the era of general American technological dominance, and of the particular dominance of other countries in some industrial sectors, has been to force up overall R and D expenditure in Britain to a level which, at 2·6 per cent of the GNP, is higher than that of any other country except the USA (3·7 per cent) and the USSR (probably between 2·6 and 3·0 per cent) (13, 22, 23). The industrial and commercial purpose behind this large expenditure, which totalled £770 million in 1964–65(14), and which is probably not much below £1,000 million today, is shown by the fact that nearly two-thirds of all R and D in Britain is carried out within industry. Nearly two-thirds of this industrial R and D is paid for by Industry itself. The remaining part of this industrial R and D, £180 million in 1964–65, is paid for by Government, and consists mostly of Defence projects, largely in the aerospace industries.

26. The amount of R and D which is carried out varies enormously from industrial sector to sector (Table 2), and, as OECD data(22) show, the pattern of industrial R and D is quite different in some other conntries from that in the United Kingdom and the USA (Table 4), with less emphasis on aircraft, considerably less in some cases, and a much stronger concentration on chemicals and metals, to such an extent that in these sectors the total European effort is comparable to the American. Were it possible to encourage a radical redistribution of industrial effort, which permitted a great increase of R and D in some sectors that at present have a small share of the total, Britain could clearly match or exceed the American R and D and innovative effort in more instances than it does at present.

27. But as already implied, a high level of R and D is far from being the main key to successful innovation. Capital investment in new manufacturing plant, dynamic management, adaptable labour, high productivity and large-scale sophisticated marketing, are every bit as vital. Capital investment in new productive capacity has not, however, been matching our outlays in R and D (13, 24, 25). In private manufacturing industry, the total investment in new plant and machinery—even when one allows for distortion caused by the aircraft firms, with only £10 million of capital investment(26) against £140 million of R and D expenditure(14)—has been only about three times that on industrial R and D. This is far too small a ratio, overall, for really effective conversion of R and D projects into commercially fruitful innovations. Of course, firms differ greatly within the industrial sectors of which they are part, and in a large number the ratio is much better than the

average. The investment grants now made for capital equipment should help improve the general situation and, as the national economy gets into steady gear, the inhibitions against capital investment which have built up in private industry may disappear.

28. The position regarding qualified manpower is equally important. Because Britain spends so heavily on R and D, it provides from its relatively small total stock of qualified scientists and engineers (QSEs) one of the largest forces of professional people working on R and D (1, 23). About one-third of all our graduate scientists and engineers in both Government and industry are so employed(14).

29. The inference from this, that relatively fewer professionally qualified technical personnel are engaged in production, management, technical sales and marketing in the United Kingdom than in some other advanced countries, is confirmed from many directions. The proportion of engineers to scientists in the national stock of graduate scientists and engineers is particularly low(14). Britain appears to use only about half as many professionally trained people, as for example Germany, in applying science and technology to production and marketing; even though it has many more trying to generate new scientific and technological knowledge(13).

30. There is additional evidence bearing on this point from individual industries. In a large international company in the oil industry, for example, only 17 per cent. of the management and professional staff in the British section of the company are graduates, compared with 90 per cent. in the American and 31 per cent. in all European sections, including the United Kingdom. A recent survey of manpower in the British electronics industry has emphasised the need for technologically trained personnel in order to raise productivity(27). A study of British and European shipbuilding industries in 1962 concluded that the ratio of managerial and technical staff to total employees in advanced continental yards was appreciably higher than in any British yard; in fact, one large Scandinavian firm claimed to employ as many as 100 graduates(28). In 1964, the graduate technical staff employed in British shipbuilding firms amounted to only 0·4 per cent. of the total employees, compared with 7·9 per cent. in a Japanese shipbuilding firm(29). Whatever the uncertainties in the standards of professional qualifications, these numerical differences cannot be treated lightly.

31. The situation is much the same in the field of management. The strength of American firms, particularly in their production schedules with strict delivery dates, and efficient use of productive resources, appears to stem largely from the employment of a very high proportion of commercially-orientated and technically trained graduates in the management of production operations(1, 30). A survey, published in 1965, of a range of British firms revealed that in the largest companies (over £5 million capital) only 8·5 per cent of directors have scientific or technical qualifications, and that the figure is 5 per cent for small companies(31). In view of the correlations that are held to exist between the profitability of companies and the proportion of executives in them with university degrees or equivalent formal qualifications (Table 5), and between productivity and proportion of salaried staff among employees(33), it is to be expected that, other things being equal, our manufacturing industries would be doing better than they already are, if more

professionally trained scientific and technical personnel were appointed to managerial posts.

32. The maldistribution within industry of our population of professionally trained scientists and technologists, as compared with what is customary in Germany and the United States is, to some extent, a reflection of our old practice of spreading our R and D effort over the broadest front possible, and of treating R and D as something apart from the rest of the industrial process. Germany, because it does not engage in so much R and D, still has enough trained manpower available for employment in the production and marketing sides of industry; while the United States, with its very much larger population, has enough trained people not only to cover the whole spectrum of R and D, but also to service its immensely powerful production and sales efforts.

33. Table 6 shows the spread of R and D effort, capital expenditure and qualified manpower, in some major British engineering industries. The balance between investment in plant and machinery, and in R and D on products and processes, is more reasonable in chemicals, electrical engineering, motor vehicles and mechanical engineering, than in most other industries, while the relatively high capital expenditure in iron and steel reflects the capital-intensive nature of this industry. By contrast, expenditure on plant and machinery is strikingly low in the research-intensive industries, aircraft, electronics and scientific instruments. To some extent this is due to the labour-intensive nature of these industries, as well as to the fact that, in aircraft, equipment is acquired during the R and D stages for the construction and testing of prototype machines. This last point is also reflected by the fact that annual R and D expenditure per professional scientist or engineer on R and D in the aircraft industry, about £33,000, is far higher than the average, about £8,000, in most other industries. (The other exceptional industry in this respect is motor vehicles, with £45,000 per qualified man, due in this case to heavy development costs on styling and road testing, neither of which calls for a large scientific staff.)

34. The problem facing industries such as aircraft, electronics and scientific instruments, which compete mainly by technological advance, is nevertheless brought out by these figures. If the R and D expenditure is maintained at the level necessary for them to be able to compete technologically with the world at large, it is then too great to be recouped from sales unless export markets far larger than the domestic market can be secured. On the other hand, if it is held down to the level where it could be recouped from domestic sales, the technological competitiveness is then insufficient to prevent foreign imports from taking over much of the domestic market.

35. At this point it is necessary to put in a qualification which derives first from the fact that the cost of professional and other industrial labour in the United Kingdom is much lower than it is in the United States*, and second from the consideration that manpower and overheads are the biggest component of total cost in the development of an advanced engineering product, including electronic engineering†. When the industrial process moves on to

---

* It is reasonable to assume an exchange rate of $6 to the pound for salaries and wages.

† On average varying between two-thirds and three-quarters of the total, the rest being material costs, whether raw material, part finished or finished components.

the production phase, the ratio is reversed, or very nearly so, and material costs, which on average are slightly lower in the United States than here, become the most important factor. What is called the 80 per cent law—a much-used rule of thumb—applies to the cost of the eventual product as output goes up ; when production is doubled, the labour cost per unit falls to about 80 per cent ; if it is redoubled, to about 64 per cent.

36. If one assumes that relatively the same technological effort is called for to produce the same advanced product, whether the job is done in the United Kingdom or the United States, it then follows that one would normally expect development costs to be far lower in this country than they are on the other side of the Atlantic. The difference could be so great as even to compensate, in the overall cost of the product (which is made up of total development costs, tooling and production costs and marketing) for the much larger American domestic market. For products which sell in hundreds rather than tens, calculation suggests that in theory we should be able to compete, even if the product run in the USA were four times what it is over here. But the theory breaks down completely when we deal with small runs of very costly products. Moreover, we could not in general afford a head-on competition to sell the same product if the United States, in addition to an assured large domestic market for the product, had already penetrated markets overseas, particularly by way of subsidiary manufacturing companies, through which they can benefit from our lower professional manpower costs.

37. Although the balance between R and D and capital investment varies from industry to industry, high research-intensiveness is not in itself a good thing. It may represent an uneconomic input of scarce and expensive resources in order to yield only a small commercial output. As a general goal we should aim at a lower research-intensiveness than at present, i.e., a smaller ratio of R and D to production, partly by building up those sectors of industry where, for reasons discussed below, the demand for R and D is less acute, and partly by mounting exceptionally intense innovative efforts on particular science-based projects to secure, by sheer technological competitiveness at the international level, the large markets without which they cannot be economically competitive. The adequacy of an R and D effort, whatever it costs, is determined entirely by its ultimate success ; and in a competitive field it is the pace-maker who says what the costs should be.

38. Nonetheless Britain, or indeed any other country economically smaller than the USA, cannot—because of capital and manpower requirements—move far in certain of the expensive technologically advanced industries without some co-operative arrangements with other countries. To concentrate its capital and R and D efforts more strongly in certain directions, the United Kingdom must reduce its efforts elsewhere and so rely more on the work of others. In exceptional industries, such as aero-engines, we have succeeded in penetrating the USA market substantially and so escaped the limitations of a small domestic market. But in general, neither Britain, nor any other country of Western Europe, can expect to make a commercial success of any large science-based project, for which the individual R and D cost runs well above £10 million, unless it has access to the whole Western European market. This is not possible so long as several countries, including ourselves, all try to do the same thing in order to protect their own

national industries. One way of achieving the ideal would be to have an agreed international division of specialities, with each country concentrating on different branches of the big-science industries. This, as we all know from experience, is more easily said than done. The alternative, which may be a less efficient way of working but is less hindered in its implementation by national aspirations, is for countries to become partners in multi-national companies. But one must guard in such organisations against the risk that the process of reaching quick technical and commercial decisions is hindered by a proliferation of committees and by a demand for excessive consultation. In the world of manufacturing and commerce anything which impedes the interaction between the manager, the development and design staff, the manufacturing plant, and the customer, is to be deprecated.

39. The problem of technological competition is, as already mentioned, less acute for our chemical, metallurgical, motor vehicle and general engineering industries than in for instance the electronic, aviation and nuclear industries. This is partly because there is a large domestic market for the bulk of the goods they produce. But the difference also reflects the fact that, in these industries, new technical ideas cannot operate freely and fully as the sole determinant of competitiveness. In the bulk chemical and steel industries, for example, the rate of technological change is greatly constrained by the rate at which massive process plant can be economically written-off. Furthermore, in many of the general engineering industries, and certainly for road vehicles, low cost is at least as important as technical advance in determining the competitiveness of the product.

40. But in spite of these differences from the more intensely scientific industries, and even though they call for much less R and D, the engineering-based industries nonetheless suffer from an insufficient innovative effort. A striking feature indicated by the export-import figures of Table 7 is the comparative neglect of opportunities in some parts of the field of high-grade machinery, where goods sell at prices in the range £10,000 down to about £1,000 per ton. The indication that the level of imports is comparable with that of exports, and that in many cases the value per ton of imports is higher than that of exports, reflects the fact that Britain in general is making the less sophisticated items in this category of manufactured goods and importing the more sophisticated. Since these are products of engineering rather than science-based industries, this position relates to the trends discussed earlier, i.e. the drain of resources and qualified manpower to R and D work in the science-based industries and the small population of engineers, as well as to the shortage of productive capacity for making the more high-grade engineering products.

41. An increase in the innovative capacity of the engineering-based industries could bring considerable economic benefits. Mechanical engineering is a very large industry, and world demand for engineering products continues to grow rapidly. Britain has an old tradition of strength in mechanical engineering; and the field is one in which a little R and D goes a long way, and in which the innovative costs of individual projects are generally not too large in relation to the size of the domestic market. There are innumerable opportunities for technical advance in the engineering

industries, particularly through small-scale innovations tailored to meet the needs of individual firms(37). A mere 10 per cent increase in exports and 10 per cent decrease in imports of mechanical engineering products would shift the balance of trade favourably by some £150 million (c.f. Table 6), which is comparable with the total exports of the largest of the research-intensive industries and with the present total innovative expenditure (both R and D, and plant and machinery) in mechanical engineering.

V. Conclusion

42. Britain is responding vigorously, by a variety of measures, to the challenge of world technological and commercial competition: by special Government support for critical industries such as computers and nuclear power; by encouragement, through the NRDC and the Industrial Research Associations, of small firms which work in fields where technological innovation does not demand vast industrial resources; by promoting industrial mergers, particularly in fields where individual projects are, of necessity, large; by sharing aircraft projects with other countries; by avoiding large space projects and so conserving resources for other fields; and by seeking ways to promote the development of industries on a continental scale throughout Europe. But the challenge is formidable and, in the face of considerable social inertia, calls for bold changes to meet it. The requirements for greater success in technological innovation and in raising productivity are easy enough to define—for example, close involvement of people engaged in R and D with those employed on production and marketing; a more sophisticated marketing approach; reduced lead-times for development projects once the decision is taken to go ahead; a more balanced distribution of resources between R and D, the later stages of innovation, production plant, and marketing; an increased flow of qualified manpower into all levels of industrial management. The problem is how to achieve these things in the face of the inertia which derives from past habits.

43. The evidence is clear that on a national scale the attractions to the professional scientist and engineer of engaging in R and D have detracted greatly from those of other spheres of industrial activity. A bigger fraction of qualified manpower must be encouraged to go into the management of industry than at present, both to develop new products and to improve in all respects the processes used for making new and existing products. Many of the recommendations of a recent Report(38), particularly concerning the flow to industry of qualified scientists and engineers from the Universities and Colleges of Technology, are immediately relevant to this problem and will not be repeated here. We also have many highly-trained and experienced research people working in Government research establishments. Recognition of the desirability of bringing them into closer relation to industry, which is generally agreed(39), has resulted in steps being taken to diversify the work of some of these establishments in directions of more

immediate interest to industry. This approach, however, still leaves the R and D man outside the control of dynamic and commercially motivated management, and its success will have to be measured by the extent to which industry is willing to support the establishments financially in such work. But it would be unrealistic to expect that such support could at any time cover more than a minor part of the activities of most establishments. There is a growing need to consider other measures, such as the short or long-term transfer of specialist staffs to industry for particular projects, and even of other resources, from Government establishments.

44. An increased flow of qualified manpower into Industry would of itself encourage more dynamic management and an increased awareness of technological possibilities in domestic and world markets. It would constitute a phase of rationalisation which could open the way to a more effective use of technological resources through the formation, where appropriate and manageable, of European-based industries. A rationalisation of the range of products manufactured and marketed would not only bring the usual economies of manufacturing scale but would also free more qualified people for production, marketing, and management. Improved productivity, which the evidence shows to be so clearly associated with the numbers of qualified people engaged in manufacturing, can in turn make possible the higher salaries which undoubtedly attract such people. Government can act, for example, by transfer of financial support from R and D to the productive parts of industry, so as to help start up this cyclic and interacting process.

45. A more discriminating and rapid selection of projects, brought about through a more rational use of our technological resources as well as through sophisticated systems analysis, including a full appraisal of market and commercial potentialities, would also lead to a better concentration of our industrial efforts. In turn this would lead to a reduction in lead-times, as well as to clearer indications of where Government support should be given to the whole process of technological innovation, in contrast to its present overwhelming emphasis on the opening phases of research and development. The scale of this problem is indicated by the fact that Britain has recently been spending not far short of £1,000 million annually on R and D as against only £2,600 million on new plant and machinery; and that the Government itself has been investing about £450 million annually on R and D at the same time as manufacturing industry has been spending only some £1,000 million on new plant and machinery.

46. In short, what we have to achieve is a new balance, both overall and in particular cases, of the deployment of our technological resources, a balance which is based on the understanding that a new technological idea, whether derived from our own inventions or bought in on a royalty basis, achieves commercial success only when it is nurtured into the final phase of marketable products which the consumer wants and the producer can make at a profit; and that the most difficult and complex problems in the process of technological innovation generally lie in this final phase, the phase which includes aggressive and sophisticated marketing.

VI. Recommendations

47. Wherever appropriate, both the Government and private industry should foster conditions which promote, both in the short and long term, effective technological innovation. The particular objectives which need to be achieved, where this has not already been done, are—

(*a*) The direct linkage of R and D, production and marketing into a single interacting operation.

(*b*) Planned programmes of innovation related to market opportunities.

(*c*) Effective technological management.

(*d*) Short lead-times.

(*e*) A balanced use of scientific and technological resources over all stages of the innovative process.

48. The measures that can be promoted by Government to help in realising these objectives are—

(*a*) The encouragement of new science and engineering graduates into the management of industrial operations as a whole, comprehending prototype work, production, and marketing, as opposed to merely research and development. This could be done partly through the negative measure of reducing the numbers of research grants made by Government institutions to new graduates, and by concentrating the support for R and D work in Government establishments on projects which are related to foreseeable production. The change could also be encouraged positively by diverting the resources so released to agencies such as the NRDC as well as to Research Associations and Governmental industrial services generally, in order to help in the post-R and D phases of manufacturing industry.

(*b*) The encouragement of small firms, through special measures such as loans and grants, to improve production methods and to exploit promising projects.

(*c*) The encouragement in firms of all sizes of an awareness of the value, when appropriate, of purchasing royalty rights from overseas in order to release scarce manpower for the later phases of the innovative process, including marketing.

(*d*) The encouragement of Government research establishments to act on a commercial basis as agencies for private manufacturing industry not only in the R and D phase, but also in the later stages of the innovative chain.

(*e*) The arrangement of adequate measures for the further run-down of Government establishments where their original specific purpose no longer justifies their present scale of effort and where they cannot provide services for industry. This would make more trained and experienced people available for employment in industry and in the schools, to supplement the additional numbers of new graduates available now that fewer grants are being given for post-graduate research in the Universities. Any measure which will help to get the pattern of our scientific, technological and manufacturing efforts into balance will pay in the long term.

49. Where agreed, Government support for industry should be provided, through the relevant agencies and by appropriate means, to help firms achieve a balanced pattern of employment of technological manpower in all stages of the productive and commercial process and, by so doing, improve the quality of their technical management. Support of this kind, provided it is not coupled with central control which slows down the process of taking decisions, will provide an opportunity to assist in concentrating nationally our inventive and manufacturing genius on projects which are economically viable and which, through concentration of resources, will enjoy the advantages of short lead-times. Particular attention should be paid to the problem of encouraging innovation in the products and processes of mechanical engineering.

50. Every possible step should be taken to rationalise the innovative efforts of United Kingdom firms, and to build up international companies which, while not slowing down the decision-making process through undue consultation and committee work, could enjoy the advantages of scale and large market.

References

(1) Report of the Third International Conference of Ministers of Science of OECD Countries, OECD Observer, April, 1968.

(2) Management of Research and Development, A Symposium. British Institute of Management, 1964.

(3) J. Ben-David, Fundamental Research and the Universities, OECD, Paris, 1968.

(4) J. Jewkes, D. Sawers and R. Stillerman, The Sources of Invention, MacMillan, 1958.

(5) Board of Trade Journal, 29th July, 1966.

(6) R. R. Nelson, M. J. Peck and E. D. Kalachek, Technology, Economic Growth and Public Policy, The Brookings Institution, 1967.

(7) C. Freeman, C. J. E. Harlow and J. K. Fuller, National Institute Economic Review, November, 1965.

(8) Report of the Committee of Inquiry into the Aircraft Industry, Cmnd. 2853, Her Majesty's Stationery Office, 1965.

(9) S. G. Sturmey, The Economic Journal, December, 1964.

(10) Technological Innovation: Its Environment and Management, US Department of Commerce, January, 1967.

(11) Industrial Research in Manufacturing Industry, 1959–60, Federation of British Industries.

(12) National Patterns of R and D Resources, National Science Foundation, NSF 67–7, 1967.

(13) B. R. Williams, Technology, Investment and Growth, Chapman and Hall, 1967.

(14) Statistics of Science and Technology, Department of Education and Science, and Ministry of Technology, Her Majesty's Stationery Office, 1967.

(15) Statistical Abstract of the United States, US Department of Commerce, 1967.

(16) Census of Production, Board of Trade Journal, December, 1965.

(17) Industrial Statistics, Statistical Office of the European Community, Table A7, 1967–J–A.

(18) Basic Statistics of the Community, EEC, 1966.

(19) Research and Development in Industry, National Science Foundation, NSF 64–9, 1964.

(20) C. Freeman, National Institute Economic Review, May, 1962.

(21) The 500 Largest US Industrial Companies, The Fortune Directory, October, 1966.

(22) C. Freeman and A. Young, The Research and Development Effort in Western Europe, North America and the Soviet Union, OECD, Paris, 1965.

(23) The Overall Level and Structure of R and D Efforts in OECD Member Countries, OECD, Paris, 1967.

(24) T. P. Hill, Economic Journal, June, 1964.

(25) The Engineering Industries in North America, Europe, Japan, 1966–67, OECD, Paris, 1967.

(26) National Income and Expenditure, Central Statistical Office, Her Majesty's Stationery Office, 1967.

(27) Manpower Studies No. 5: Electronics. Ministry of Labour, Her Majesty's Stationery Office, 1967.

(28) Productivity and Research in Shipbuilding. Report of the Main Committee to the Joint Industry Committee, 1962.

(29) R. L. Townsin, Shipbuilding and Shipping Record, 16th November, 1967.

(30) New Technology, Ministry of Technology, March, 1968.

(31) The Director, January, 1965.

(32) J. H. Dunning, Business Ratios, Autumn, 1966.

(33) Board of Trade Journal, 16th February, 1968.

(34) Based on Table V.I. Exploring 1970, Department of Applied Economics, Cambridge, Chapman and Hall, 1965.

(35) Overseas Trade Accounts of the United Kingdom, December, 1967, Her Majesty's Stationery Office, 1967.

(36) Overseas Trade Accounts of the United Kingdom, December, 1966, Her Majesty's Stationery Office, 1966.

(37) D. F. Galloway, The Technology, Economy and Philosophy of Improving Productivity in the Manufacturing Industries, The Institution of Production Engineers, 1968.

(38) Report of the Working Group on Migration, Cmnd. 3417, Her Majesty's Stationery Office, 1967.

(39) See for example, Exploiting Technology, The Institution of Professional Civil Servants, March, 1968.

TABLE 1

COMPARATIVE OUTPUTS OF MANUFACTURING INDUSTRIES

Industry	Research Intensive-ness (R and D as per cent of net output)*	Output as per cent. of all Manufacturing Industry			
		USA 1965 (15)	UK 1963 (16)	Germany 1963 (17, 18)	France 1963 (17, 18)
Aircraft	39	3·9	3·1	0·3	2·0
Electronics	14	4·8	3·7	3·1	2·0
Petroleum Products	13	1·9	0·7	3·0	4·9
Scientific Instruments, Clocks ...	6	2·4	1·5	1·5	1·8
Chemicals	5	9·1	9·3	8·5	7·6
Motor Vehicles	4	7·6	7·1	5·6	6·3
Electrical Engineering	4	4·5	5·6	5·7	5·0
Rubber	2	2·6	1·7	1·4	1·7
Mechanical Engineering ...	2	10·6	14·5	19·7	12·1
Glass, Pottery, Bricks	2	3·6	4·1	4·4	3·7
Primary Metals	2	8·8	7·9	8·9	9·5
Ships and Marine Engineering...	1	0·7	2·0	0·6	1·0
Textiles	1	3·5	8·0	5·0	6·7
Food, Drink, Tobacco	1	11·8	12·2	14·8	11·0
Timber, Furniture	†	3·6	2·7	4·8	4·5
Paper, Printing, Publishing ...	†	9·4	8·5	4·7	6·1
Clothing, Footwear, Leather ...	†	5·1	4·5	4·7	5·0

* = U.K. figures. R and D data from reference 14.

† = Less than 0·5 per cent.

TABLE 4

COMPARISON OF NATIONAL R AND D EFFORTS IN MANUFACTURING INDUSTRIES (22)

Industry	DISTRIBUTION OF MANUFACTURING R AND D AMONGST INDUSTRIES (Percentages)								
	United Kingdom	United States		Belguim 1961	France	Germany	Norway	Canada	
	(*1*)	(*1*)	Product Field	(*1*)	(*1*)	(*1*)	(*1*)	Product Group	(*1*)
Aircraft	35·4	36·3	35·3	0·8	27·7	19·2	2·2	15·7	17·5
Vehicles	3·0	7·4	5·1		2·6			1·5	
Machinery	7·3	8·2	7·6	8·0	6·4		5·2	5·5	4·3
Electrical Machinery	21·7	21·6	24·1	19·4	25·7	33·8	26·8	22·3	19·3
Instruments	2·3	3·9	2·1	n.a.	n.a.		n.a.	1·0	n.a.
Chemicals	11·6	12·6	10·4	39·6	16·8	32·9	24·4	24·4	22·3
Steel and Metal Products	2·9	2·0	2·4	13·3	3·2	6·6	26·2	14·2	8·5
Non-ferrous metals	1·2	0·6							
Stone, clay and glass	1·3	1·0	0·5	(*2*)	1·2	0·8	3·2	(*2*)	1·2
Rubber	1·2	1·1	0·7		(*2*)	1·0	0·5		1·2
Paper	0·9	0·6	5·4			0·6	4·2	5·4	6·2
Food and drink	1·9	0·9		2·6		0·6	2·7	10·0	2·4
Other manufacturing	3·4	2·0		13·0		1·9	3·3		5·7
Transport and energy	4·4	n.a.	5·4	3·3	9·0	0·6(*3*)	n.a.		2·7
Other non-manufacturing	1·6	1·9	n.a.	n.a.	2·4	2·0	1·3	n.a.	8·8

Notes: (*1*) Companies are classified to the industry of their principal activity. The " product field " figures give a classification according to the products of R and D, as distinct from the principal activities of the companies performing the R and D.

(*2*) Included under other categories.

(*3*) Energy only.

n.a. = Not available.

TABLE 5

PROFITABILITY OF UNITED STATES AND UNITED KINGDOM FIRMS IN RELATION TO THE QUALIFICATIONS OF EXECUTIVES (32)

Proportion of Executives with University Degree or Equivalent Formal Qualifications %	Relative Profitability	Number of Firms in Sample
75 to 100	23·8	18
50 to 74	19·5	29
24 to 49	17·9	31
0 to 24	13·5	26

TABLE 6

INNOVATIVE EFFORT, OUTPUT AND OVERSEAS TRADE IN SOME BRITISH ENGINEERING INDUSTRIES

Industry	Research Intensiveness (Table 1)	Innovative Effort				Net Output			Overseas Trade		Exports–Imports / Net Output
		Expenditure (£M)		Qualified (QSE) Manpower (thousands) 1965		1963 £M	Growth Rate % per year	1966 (estimated) £M	Exports* 1966 £M	Imports 1966 £M	
		R and D 1964–5 (14)	Plant and Machinery 1965 (26)	On R and D (14)	Total (14)	(16)	(34)	.	(35)	(35)	
Aircraft	39	138	10	4·2	6·9	312	4·5	390**	134	24	0·3
Electronics ...	14	71	[25]	7·1	11·8	382	[10·0]	600***	[125]	[50]	0·1
Instruments, Clocks... ...	6	10	[10]	n.a.	n.a.	157	[7·5]	210	158	119	0·2
Chemicals ...	5	55	181	7·2	17·4	952	5·4	1,180	480	294	0·2
Motor Vehicles ...	4	32	60	0·7	2·8	721	5·8	850	578	64	0·6
Electrical Engineering ...	4	26	[45]	3·5	9·2	593	[5·0]	800	[230]	[100]	0·2
Mechanical Engineering ...	2	31	[100]	5·2	21·3	1,318	[5·0]	1,780	1,072	430	0·4
Iron and Steel ...	2	10	70	[1·5]	[6·0]	627	4·4	740	216	88	0·2
Ships	1	3	4	n.a.	n.a.	208	1·2	230	50	10	0·2

n.a. = Not available.
[ ] = Estimated value.
* Includes re-exported imports.
Expenditure is at current prices for the years indicated at the head of relevant columns.
** Conversion to current price based on Group VIII of the Standard Industrial Classification as there are no output price indices for aircraft.
*** Conversion to current price based on combined input price indices as output price indices for electronics are rather unsatisfactory.

TABLE 7

BRITISH EXPORTS AND IMPORTS OF MACHINERY AND TRANSPORT EQUIPMENT IN 1966 (35)

Product	Overseas Trade, £m.			Value £'000 per ton	
	Exports*	Imports	Net Exports	Exports	Imports
Aircraft	134	24	110	[50]	
Aircraft Engines	83	33	50	21	15
Scientific Instruments, Clocks ...	158	119	39	[20]	
Computers	14	31	−17	16	21
Office Machinery	68	54	14	4·4	7·9
Type-setting Machinery... ...	7·5	2·2	5·3	2·1	3·0
Circular Knitting Machinery ...	5·8	2·9	2·9	3·2	3·0
Flat Knitting Machinery ...	5·9	1·4	4·5	1·3	2·0
Tyre Making Machinery ...	0·7	1·3	−0·6	1·4	1·6
Pumps, Centrifuges	51	25	26	1·0	1·3
Machine Tools	44	39	5	0·85†	1·25†
Motor Vehicle Engines	38	3	35	0·49	0·81
New Motor Cars	234	27	207	0·5	n.a.
Combine Harvesters	4·3	5·0	−0·7	0·4	0·34
Tractors	106	1·7	104	0·4	0·4

* Includes re-exported imports.

[ ] = Estimated value.

n.a. = Not available.

† 1965 values; see reference 36.

(863580) Dd. 142675 K16 9/68 St.S.

CENTRAL ADVISORY COUNCIL FOR SCIENCE
AND TECHNOLOGY

Technological Innovation in Britain

July 1968

LONDON
HER MAJESTY'S STATIONERY OFFICE
1968

THE CENTRAL ADVISORY COUNCIL FOR SCIENCE AND TECHNOLOGY

Membership

SIR SOLLY ZUCKERMAN, O.M., K.C.B., F.R.S. (*Chairman*)

SIR ERIC ASHBY, F.R.S.

PROFESSOR P. M. S. BLACKETT, O.M., C.H., P.R.S.

DR. A. H. COTTRELL, F.R.S.

THE RT. HON. FRANK COUSINS, P.C., M.P.

DR. F. S. DAINTON, F.R.S.

DR. F. E. JONES, F.R.S.

SIR HARRIE MASSEY, F.R.S.

PROFESSOR R. C. O. MATTHEWS (Appointed 29.11.67)

PROFESSOR A. B. PIPPARD, F.R.S.

DR. L. ROTHERHAM, F.R.S. (Appointed 8.2.68)

SIR HUGH TETT (Resigned 27.12.67)

PROFESSOR BRUCE R. WILLIAMS (Resigned 27.11.67)

MR. R. D. YOUNG

SECRETARIAT

DR. F. H. ALLEN

DR. T. SWAIN

The Central Advisory Council for Science and Technology was established on 17th January 1967 " To advise the Government on the most effective national strategy for the use and development of our scientific and technological resources."

10th July 1968

Dear Prime Minister,

I beg to submit a Report of the Central Advisory Council for Science and Technology on the subject of Technological Innovation in Britain. The Council wish me to bring their findings and recommendations to your attention.

Yours sincerely,
(*Signed*) S. ZUCKERMAN

The Rt. Hon. Harold Wilson, O.B.E., M.P.
Prime Minister and First Lord of the Treasury

CONTENTS

Page

I. INNOVATION AND INVENTION 1

II. THE PROBLEM 1

III. CONDITIONS FOR SUCCESSFUL INNOVATION 3

IV. INNOVATIVE EFFORT IN BRITAIN 8

V. CONCLUSION 14

VI. RECOMMENDATIONS 16

REFERENCES 18

TABLES 19

TABLE 1 Comparative outputs of manufacturing industries 19

TABLE 2 Comparison of British and American R and D efforts in manufacturing industries 20

TABLE 3 Comparison of large United States and United Kingdom/Europe corporations 21

TABLE 4 Comparison of national R and D efforts in manufacturing industries 22

TABLE 5 Profitability of United States and United Kingdom firms in relation to the qualifications of executives 23

TABLE 6 Innovative effort, output and overseas trade in some British engineering industries 24

TABLE 7 British exports and imports of machinery and transport equipment in 1966 25